Extended Limits of WIPL-D on PCs

Drazen S. Sumic[1] and Branko M. Kolundzija[2]

[1] WIPL-D Ltd, drazen.sumic@wipl-d.com

[2] Department of Electrical Engineering, University of Belgrade, kol@etf.bg.ac.yu

Abstract: In the process of electromagnetic modeling and simulation, one encounters various limits imposed by the hardware capabilities of modern computers. As the complexity or the electrical size of the problem grows, so does the need for faster processors and more RAM in order to make the analysis of such projects feasible. With the era of 64 bit computing at our door step, 4GB is no longer the theoretical maximum addressable memory space on PC computers, which allows the analysis of demanding electromagnetic problems on every desktop. In this paper, several tests have been presented regarding the analysis of a cube of dimensions up to 30λ x 30λ x 30λ. Significant advancements in modeling and analysis of electrically large structures in WIPL-D Pro code are the main focus. Tests include: running WIPL-D Pro code in the Windows and Linux 64-bit environments, employing 2 processors in parallel and speed comparisons between the latest and previous versions of the code.

Keywords: WIPL-D, more than 2GB of RAM, 64 bit computing, dual processor.

1. Introduction

With the advent of 64 bit computing, the painful limit of the addressable memory space of personal computers (4 GB thereotically, but in practice 2-3 GB), was eliminated. Hence, our perception of electrically large problems shifts slowly upwards, and so do the demands that engineers set to EM simulation tools running on their PCs. The advancements recently made in the WIPL-D Pro 3D electromagnetic solver are illustrated in this paper on the example of a metallic cube scatterer with a surface of up to 5400 λ^2.

In Section 2, the simulation setup is explained in detail.

In Section 3, a speed comparison between versions 4.1 and 5.1 of WIPL-D Pro is given in order to illustrate the performance of the new, redesigned LU decomposition algorithm. The simulated project is a cube scatterer with a side varying from 3λ to 18λ.

In Section 4, the cube scatterer is analyzed on SuSE Linux system running on AMD Opteron 64-bit processor using 8GB of RAM. The analysis is performed up to 30,000 unknowns which is enough to represent a 5400 λ^2 cube using 2 symmetry planes. This is followed up in Section 5, by a speed comparison between simulations performed on Windows XP and Linux running on the same hardware.

In Section 6, parallel run of multiple WIPL-D projects was investigated on Windows, running on a dual processor Opteron system.

Conclusions are deduced based on acquired results.

2. Simulation Setup

The examined metallic cube scatterer is shown in Figure 1. The model was created in WIPL-D Pro 5.1, using 2 symmetry planes. The electrical size of patch length was kept constant at 1.5λ

Report Documentation Page

Report Documentation Page					Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **01 JAN 2005**		2. REPORT TYPE **N/A**			3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Extended Limits of WIPL-D on PCs**					5a. CONTRACT NUMBER
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **WIPL-D Ltd**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S)
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**					
13. SUPPLEMENTARY NOTES **See also ADM001846, Applied Computational Electromagnetics Society 2005 Journal, Newsletter, and Conference., The original document contains color images.**					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**4**	

throughout the simulation, while the electrical size of the cube as a whole was increased by increasing the frequency and the number of metallic patches per cube side.

The cube scatterer was excited by a linearly polarized plane wave in the cross-section of the two symmetry planes, orthogonal to one of the sides of the cube, as shown in Figure 1.

The RCS in all projects was calculated in the incident plane, in 1801 directions, from Theta=0° to Theta=180°. One quarter of the RCS diagram in case of the largest cube scatterer with the side of 30λ is shown in Figure 2.

3. Faster Linear System Solution in WIPL-D Pro 5.1

When method of moments is applied in electromagnetic simulation, the linear operator equation is reduced to a system of linear equations. Thus, the analysis duration consists of the system matrix fill-in time, the time needed to solve the linear system and the data post-processing time.

Disregarding the data post-processing time, the analysis duration can be described as:

$$T = AN^2 + \frac{1}{3}BN^3 \tag{1}$$

where A is the fill-in time of a single matrix element, B is the time needed to perform one basic operation (one addition and one multiplication) while solving the linear system, and N is the number of unknowns.

With electrically large structures, the largest amount of time is spent on LU decomposition, which is most often applied in order to solve the system of linear equations. Thus, this part of the analysis is the most interesting one to be optimized in order to reduce total analysis duration.

From version 5.1 onwards, the LU decomposition performed in WIPL-D Pro has been redesigned. The algorithm has been optimized for faster memory usage and computation. This resulted in significant speed increase for projects with medium and large number of unknowns. A diagram illustrating the acceleration of version 5.1 compared to the version 4.1 is presented in Figure 3. The acceleration is obtained by simply dividing the duration of LU decomposition in v4.1 by the duration of LU decomposition in v5.1 for the cube scatterer project described in the previous section. The acceleration is about 50% lower if it is calculated taking total analysis duration into account, including matrix fill-in time and data post-processing.

4. Cube Scatterer Benchmark – up to 5400 λ^2

Let us now observe a practical example and calculate the values A and B from (1) based on the experimental results. Ten cube scatterers were analyzed on SuSE Linux operative system running on a 1.4 GHz AMD Opteron processor with 8 GB of RAM and bus clock rate of 133 MHz. The diagram in Figure 4 was obtained by increasing the electrical size of the cube, and thus increasing the number of unknowns, and measuring the duration of the analysis. It displays the total analysis duration of a cube scatterer versus the number of unknowns. Sides of the corresponding cubes are from 3λ at 300 unknowns up to 30λ at 30,000 unknowns.

The values for A and B calculated based on the cube scatterer benchmark are given in Table 1. If we disregard the values corresponding to the first project, with 300 unknowns, results for the values A and B are a stable estimation.

5. Speed Comparison Between Linux and Windows

Cube scatterer projects of up to 15,000 unknowns were run on WIPL-D Pro v5.1 on SuSE Linux 9.0 and Windows XP 64 on the same hardware platform: AMD Opteron at 1.4GHz with 8 GB of RAM, bus clock rate 133 MHz. The results are given in Figure 5.

The Windows version of WIPL-D Pro 5.1 performs better than the Linux version for about 25% at 2700 unknowns and about 14% at 14,700 unknowns. The possible reasons for differences in speed are numerous, one of them surely being the different compilers used to build applications on two operative systems. One other possible reason is different memory management on these two systems.

6. Running Multiple WIPL-D Projects in Parallel

Employing more than one processor at a time allows significant speed up of the electromagnetic modeling and simulation process. On dual processor systems, the time needed for the analysis is almost halved.

Running multiple WIPL-D projects on more than one processor was tested on a system with two AMD Opteron processors at 1.4 GHz, using 8 GB of RAM. Since WIPL-D Pro code is not parallelized, multiple projects were run at the same time as part of a batch procedure, thus letting the operative system take on the task of employing both processors. Each batch procedure consisted of 30 identical metallic cube scatterers in order to establish the exact speed increase compared to the execution of a single project.

The results are displayed in Figure 6. The acceleration is calculated by dividing the time needed to execute 30 projects employing only one processor with the time needed to execute those 30 projects employing both processors. The number of tasks simultaneosly assigned to a dual processor system is denoted with x. From the results we can observe that the acceleration is less than 2, which is expected since both processors use the same memory. It is also apparent that if we overload the two processors by simultaneously assigning 4 tasks with a relatively small number of unknowns to them, we achieve a small performance increase, compared to the case when only two simultaneous tasks are assigned. As the size of the tasks becomes larger, the performance deteorirates and converges to the case of not-overloaded processors.

7. Conclusions

The performance of WIPL-D Pro code in analysis of electrically large structures was investigated in this paper. A metallic cube scatterer was taken as a benchmark project.

The calculations were performed with WIPL-D Pro 5.1, featuring the redesigned LU decomposition routine which increased its speed significantly compared to the previous versions. In case of the metallic cube scatterer the acceleration was about 18 times at 15,000 unknowns (a cube with a 12λ side), taking into account all the segments of the analysis. This increase was even greater, it went up to 30 times, when just the LU decomposition part of the analysis was observed.

The metallic cube scatterer of a side from 3λ to 30λ was analyzed on a 64 bit system, demonstrating the breaking of the 2 GB memory limit. The analysis time for the cube of dimensions 30λ x 30λ x 30λ, on a 1.4 GHz Opteron processor was about 14 hours.

Multiple projects were run in parallel on a two-processor system. Speed increase close to 2 times was demonstrated.

Number of unknowns	Total analysis duration [sec]	Matrix fill-in time [sec]	Data post-processing time [sec]	Matrix inversion time [sec]	A[micro sec]	B [nano sec]
300	2.6	0.5	2.0	0.1	5.56	11.11
1200	19.6	7.6	8.7	3.3	5.28	5.73
2700	94.3	37.8	20.5	36.0	5.19	5.49
4800	371.3	124.0	36.5	210.8	5.38	5.72
7500	1143.9	298.1	57.2	788.6	5.30	5.61
10800	3099.5	612.2	83.7	2403.6	5.25	5.72
14700	7398.4	1147.4	113.9	6137.1	5.31	5.80
19200	15558.6	1932.0	150.9	13475.7	5.24	5.71
24300	32304.5	3080.3	192.3	29031.9	5.22	6.07
30000	57546.8	4666.9	239.7	52640.2	5.19	5.85

Table 1: Values A and B calculated based on cube scatterer benchmark

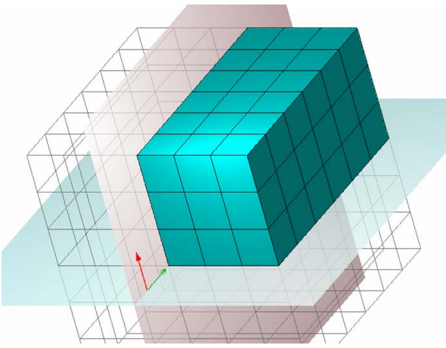

Figure 1: Cube scatterer modeled in the program WIPL-D Pro 5.1

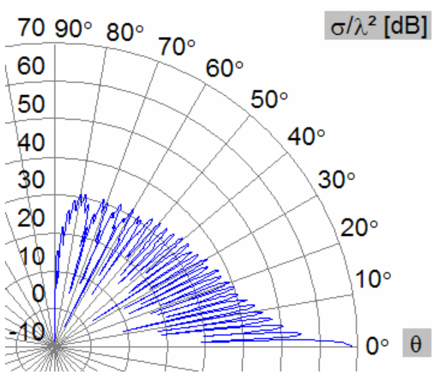

Figure 2: RCS of the cube scatterer with the side of 30λ

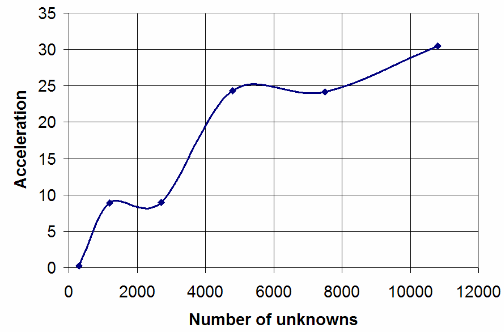

Figure 3: Acceleration of WIPL-D Pro v5.1 compared to v4.1 – LU decomposition

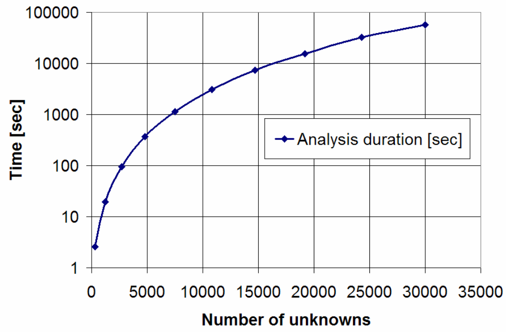

Figure 4: Cube scatterer benchmark up to 30,000 unknowns

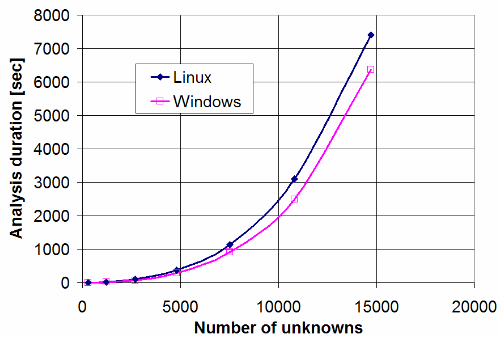

Figure 5: Speed comparison between Linux and Windows versions of WIPL-D Pro 5.1

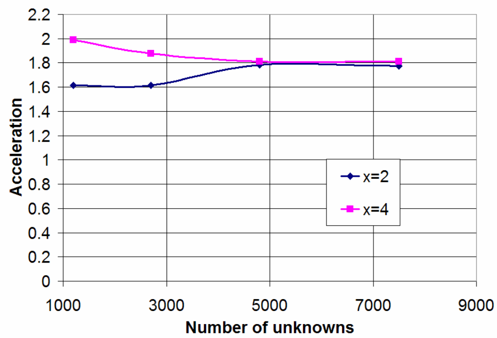

Figure 6: Acceleration in the case of dual processor run; x – number of tasks simultaneously assigned

8. References

[1] B.M. Kolundzija, A.R. Djordjevic *Electromagnetic Modeling of Composite Metallic and Dielectric Structures,* Artech House, Norwood MA., 2002

[2] *WIPL-D Pro User's Manual,* WIPL-D Ltd., 2004